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FIELD MULTICOUPLER STUDY FOR
INTERMODULATION PRODUCTS AND PARASITIC
OSCILLATIONS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Parasitic oscillations and intermodulation products occurring in HF multicouplers used at large antenna array sites are measured and analyzed. Both on-site and laboratory data are used to illustrate the signature of these undesirable signals which are readily analyzed using a 3-axis (time vs. frequency) display. Conclusions and recommendations are offered.		

PREFACE

Much of the material presented in this report has been extracted from a thesis for the degree of Electrical Engineer by E. J. Cummins, Jr.* In addition, material has been used from field laboratory notebooks and working papers prepared during and after measurements of signals and noise at a number of CDAA (Circularly Disposed Antenna Array) sites in the U.S., Europe, and the Pacific. During these visits parasitic oscillations and intermodulation products from multicouplers were found to be a major source of undesired and harmful RFI which severely limited the usefulness of the CDAA's for special measurements. The parasitic oscillation and intermodulation product data obtained during these field measurements have been assembled for presentation in this report.

*E. J. Cummins, Jr., "High Frequency Radio Interference," Thesis, U.S. Naval Postgraduate School, Monterey, California, March 1979.

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1. INTRODUCTION

Large-scale receiving sites generally have a multiplicity of antennas which drive a large number of receivers. Each antenna must be able to drive several receivers, and multicouplers are employed as the interface between each antenna and its receivers. In addition multicouplers are often employed to combine signals from various antenna elements to form monitor beams, sector beams, omnidirectional patterns, and other special arrangements.

An HF multicoupler normally consists of a preamplifier of modest gain followed by isolators for its various outputs. A typical multicoupler might have one input and eight outputs with an overall gain of about 3 dB. It is obvious that if one or more multicouplers generate spurious signals, either intermodulation products or parasitic oscillations, undesired and false signals will be input to the receivers. Receiving equipment and operators must then be capable of discriminating between real and false signals. In addition, these false signals are often large enough to mask out the desired signals.

Field measurements were recently completed at a number of CDAA sites where parasitic oscillations and

intermodulation (IM) products originating from multicouplers were an important and unwanted source of interfering signals and noise. Examples of in-band and out-of-band parasitic oscillations and IM products are provided to illustrate the problems encountered during the field measurements. In addition, laboratory measurements of intermodulation product generation in multicouplers were made to supplement the field measurements.

Technical specifications for multicouplers were reviewed to better understand equipment design features and to provide recommendations for possible future units which would be more immune to parasitic oscillations and intermodulation product generation. Since large numbers of multicouplers are employed in communications sites (500 to 1000 per site), the cost per unit must also be considered.

2. PARASITIC OSCILLATIONS

During measurements at CDAA sites parasitic oscillations were encountered in two types of multicouplers: the CU-1099/FRR Antenna Coupler and the CU-1280 Beamforming Coupler. Several examples of these parasitic oscillations are given to illustrate the types of broadband signal structures found. Parasitic oscillations in the CU-1280 coupler were discovered towards the end of the field measurement effort; thus the full-extent of the problem may not be known. Examples are also provided to illustrate the out-of-band oscillations found.

Parasitic oscillations in the CU-1280 model coupler were found while employing a CDAA in the Pacific area for broadband measurements. Mr. James Tomitagawa, a NAVSEETACTPAC engineer, was aware of the parasitic oscillations, and he intended to continue the investigation beyond the examples reported in this paper. Figure 1 shows two views of the output of a CU-1280. In the upper view multicoupler output signals are shown over the 0 to 100 MHz band. HF signals received by the antenna are shown in the 1 to 30 MHz portion of the view. In addition strong parasitic oscillations are shown spaced at about 10.3 MHz increments across the entire 0 to 100 MHz frequency range. The strongest component had an amplitude of -4 dBm at 75.339

MHz. This frequency was outside the normal operating range of the CU-1280 (and outside the HF band). The frequency region around the strongest parasitic oscillation was further examined in the bottom view of Figure 1 to define the fine scale spectral structure of the 75.339 MHz parasitic component. Additional structure was found at a level of about -50 dBm along with the numerous weak background parasitic signals at about -70 dBm.

A second example of CU-1280 coupler self-oscillation is shown in the upper view of Figure 2. Again, the maximum amplitude of the self-oscillation was in the 75 to 80 MHz region, but the spectral structure was considerably different than the previous example. Most parasitic oscillation energy was confined to the 60 to 90 MHz region and the lower frequencies appeared free from undesired oscillations. The maximum oscillation level was about -18 dBm, somewhat lower than shown in Figure 1. Additional tests were made on the two CU-1280 couplers to ascertain that the undesired signals were generated in the multicoupler. The oscillations continued when the input cables were removed; all other signals received from the antenna disappeared.

There was neither the time nor the opportunity to study the CU-1280 parasitic oscillation problem further.

The offending multicouplers were removed and replaced so other measurements could proceed. Thus, no explanation can be offered for the mechanism creating the CU-1280 self-oscillations.

Figures. 3 through 6 show examples of parasitic oscillations found in the CU-1099/FRR multicouplers employed at a number of communications sites. In Figure 3 the signature of an in-band oscillation found near 18 MHz is shown in a 3-axis format. When first observed it was assumed that the signal originated from an external source, and considerable effort was expended to locate the source of this unusual and complex signal. However, the effort revealed that the signal originated from a specific CU-1099/FRR unit. When identified, the offending unit was removed and marked for repair.

The distinctive signature of the CU-1099/FRR self-oscillations on the 3-axis display enabled field measurement personnel to rapidly identify and locate such parasitic oscillations. Upon arrival at a new CDAA or other site, the display was first used to find parasitic oscillations and to identify and replace all improperly operating CU-1099/FRR multicouplers.

Most CU-1099/FRR oscillations generated spectral components over about a 200 to 500 kHz wide band. At times these spectral component bands are so numerous and are clustered so closely that they present the wide band spectrum of Figure 4, where amplitude varied across the 2.5 to 7.5 MHz band. The peak amplitude was about -10 dBm near 2.5 MHz, decreasing to about -20 dBm at 7.5 MHz. Three very strong normal signals can be seen which exceeded the oscillation amplitude level. All other HF signals were covered up by the oscillation. When one considers that a signal of -100 dBm is normally of sufficient level for satisfactory reception, and the wideband oscillation was 80 to 90 dB stronger than this, the magnitude of the self-oscillation problem becomes evident.

Figure 5 shows another example of a self-oscillation from a CU-1099/FRR multicoupler. The distinctive pattern of the oscillation in the bottom view was easily recognized. The oscillation was about 500 kHz wide with maximum amplitude near 6.4 MHz. Amplitude variations across the 500 kHz wide band of the view are shown in the upper view of Figure 5. The amplitude near 6.4 MHz was about -50 dBm. Two -55 dBm signals can also be seen at 6.4 and 6.45 MHz. A third signal can be seen near 6.7 MHz at a level of -75 dBm which was about 10 dB below the parasitic oscillation level. All three signals should have been received with excellent

signal-to-noise ratios, but the presence of the parasitic oscillation prevented their reception with a modern HF receiver.

During a subsequent visit to another site an attempt was made to further investigate the characteristics of the CU-1099/FRR oscillations. An oscillating multicoupler was located during the initial tests with the 3-axis display. and the offending unit was removed for bench testing. Normal operation was achieved during initial bench tests. Heated air was applied to the unit to better simulate the operational environment, and parasitic oscillations began to form. Figure 6(a) shows the oscillations when heat was first applied. A few seconds later the oscillation increased in level and frequency width to that shown in Figure 6(b). Further measurements revealed that two of the three power supply voltages had excessive ripple, which was related to the oscillation. Figure 6(c) shows the ripple on the -19 volt supply and Figure 6(d) shows the ripple on the -3 volt bias power supply.

It was concluded that four factors contributed to the generation of parasitic oscillations in the CU-1099/FRR multicouplers. They were:

- a. Variations in transistor parameters and poor physical layout.
- b. Deterioration of transistor parameters due to age.
- c. Heat.
- d. Power supply ripple.

In summary, parasitic oscillations within the operating frequency range of the multicouplers (usually 1.8 to 30 MHz) had a disastrous impact on the reception of HF signals by receivers fed with a faulty multicoupler. While detection of these oscillations can be a normal and straightforward procedure, site personnel were not equipped with adequate instrumentation for the rapid identification and isolation of offending multicouplers.

Out-of-band parasitic oscillations did not always cause direct interference to received signals. However, such signals altered the normal operating conditions of the amplifier's transistors and lowered their dynamic range.

This made multicouplers with out-of-band oscillations much more susceptible to intermodulation effects from normal signals within the HF band. Again, the identification of intermodulation effects and their source required equipment not always available to site personnel.

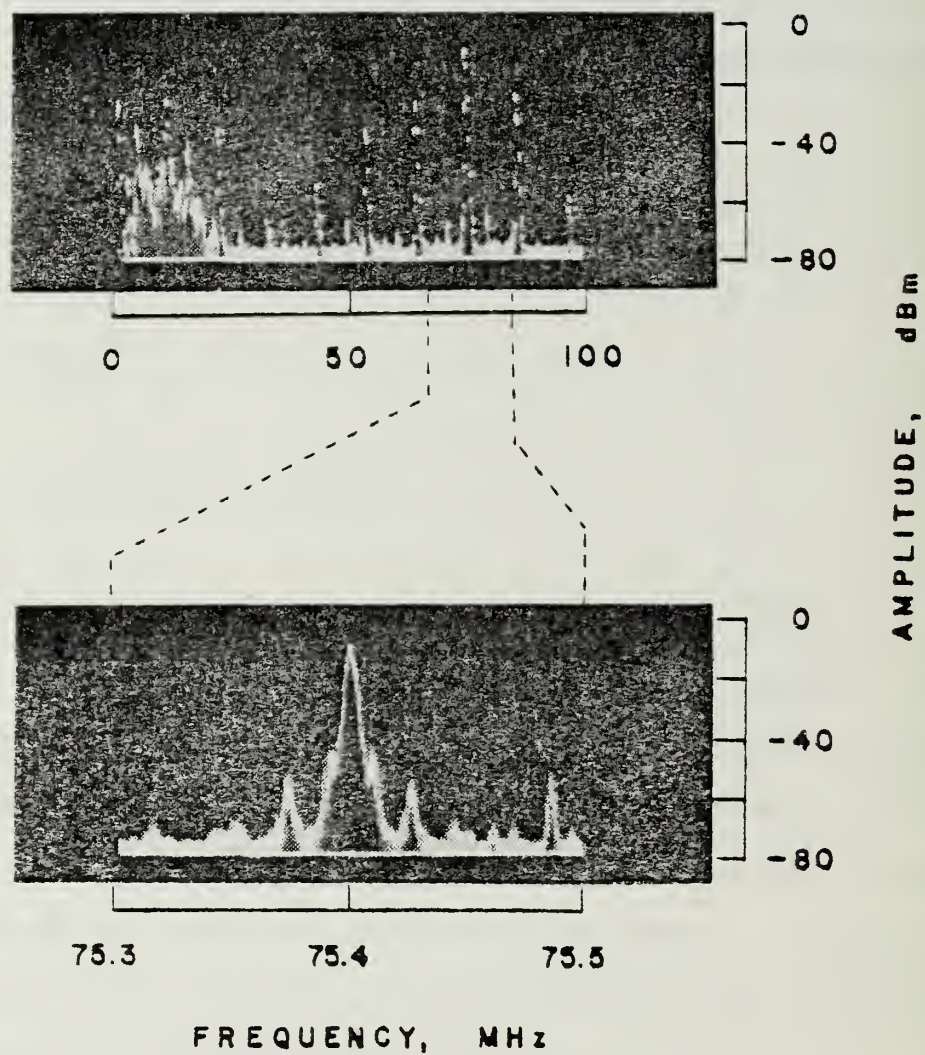


Figure 1. Parasitic oscillations across 100 MHz spectrum from CU-1280 multicoupler.

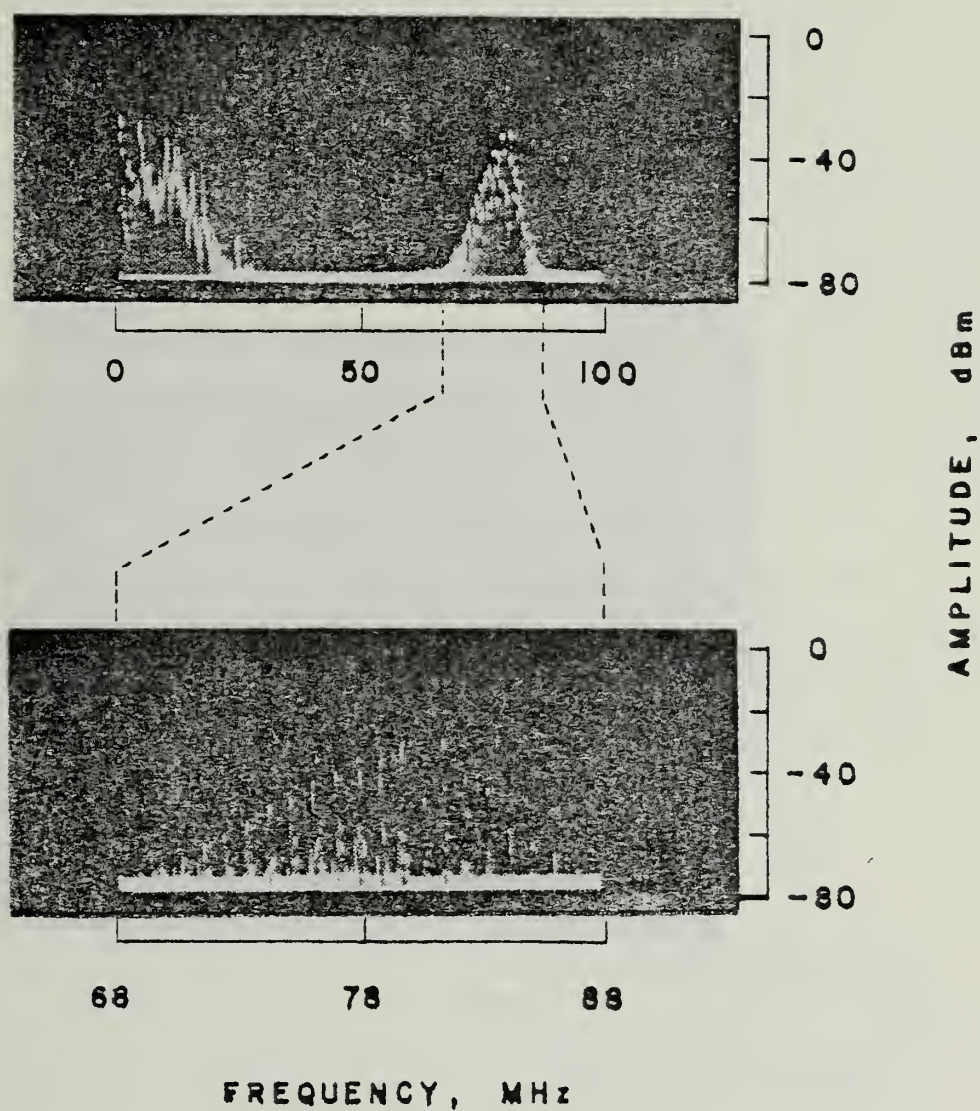


Figure 2. Parasitic oscillations between 60 and 90 MHz from CU-1280 multicoupler.

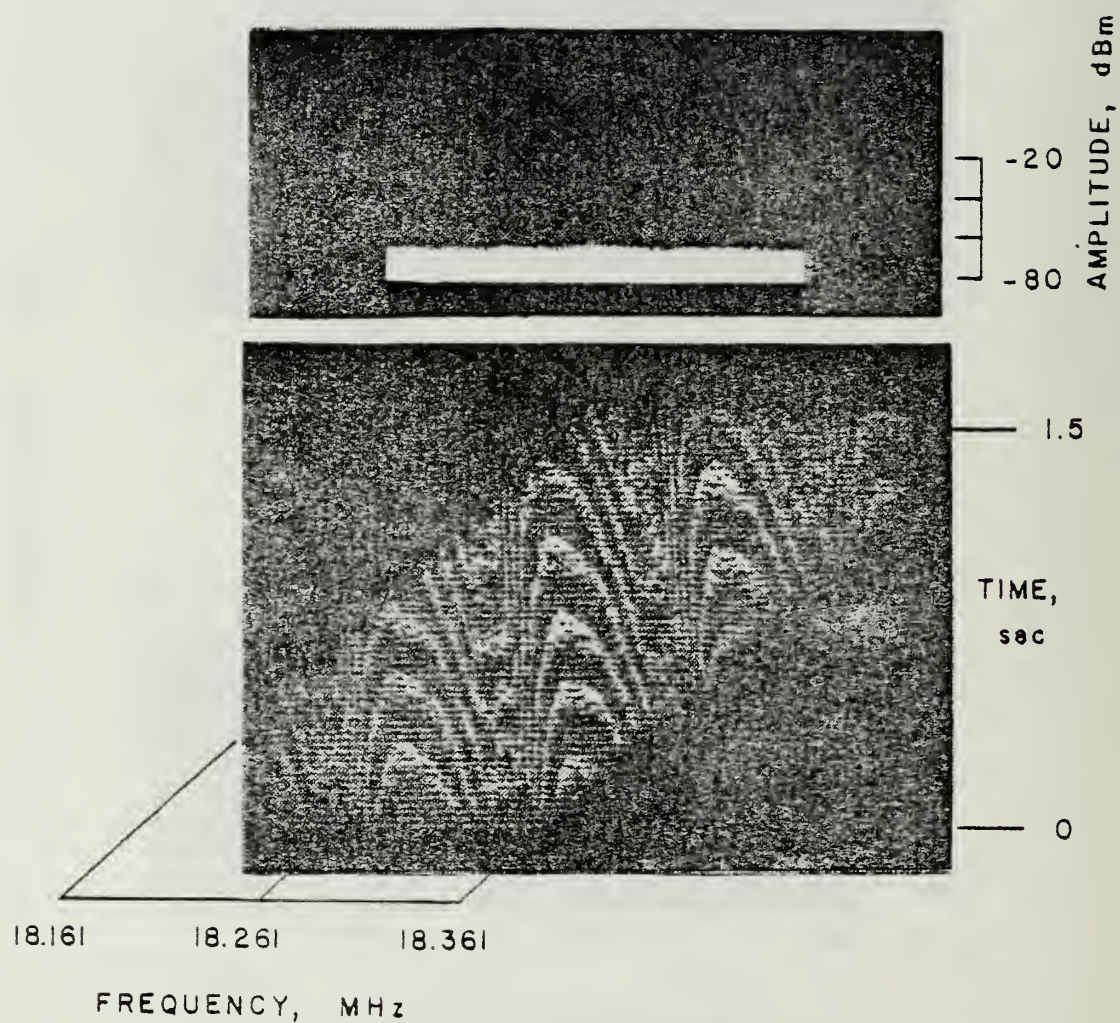


Figure 3. Parasitic oscillations in a 200 kHz bandwidth from a CU-1099 multicoupler.

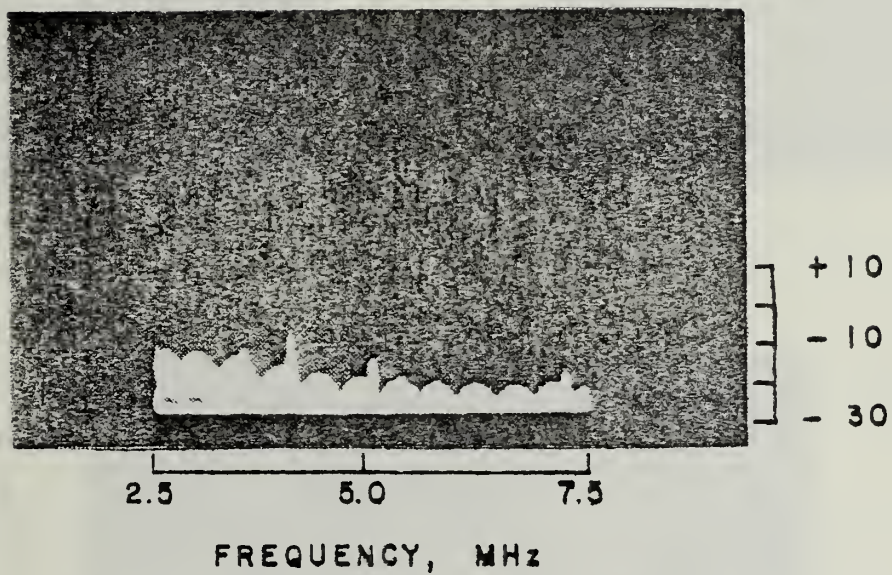


Figure 4. Parasitic oscillations in a 5 MHz bandwidth from a CU-1099 multicoupler.

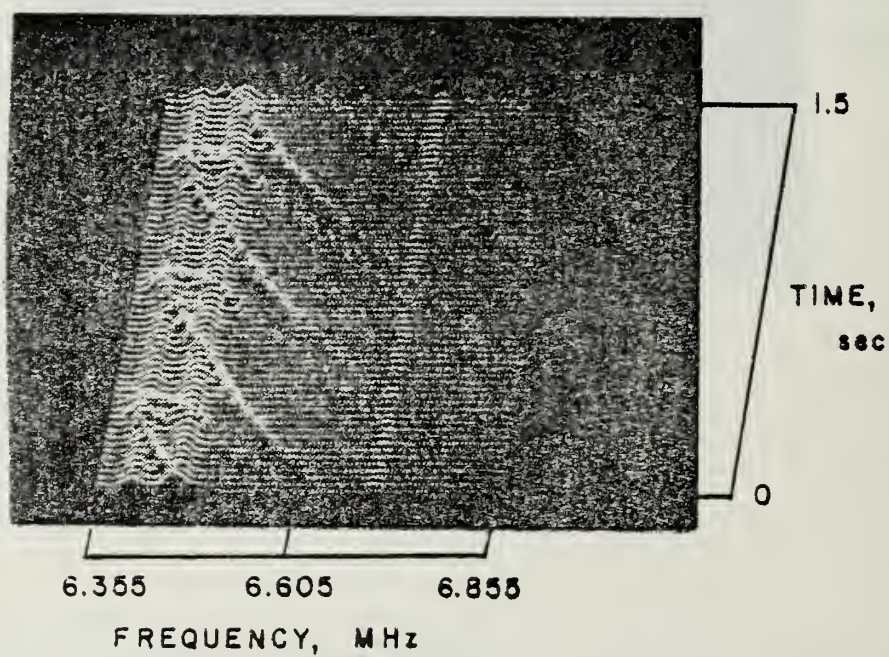
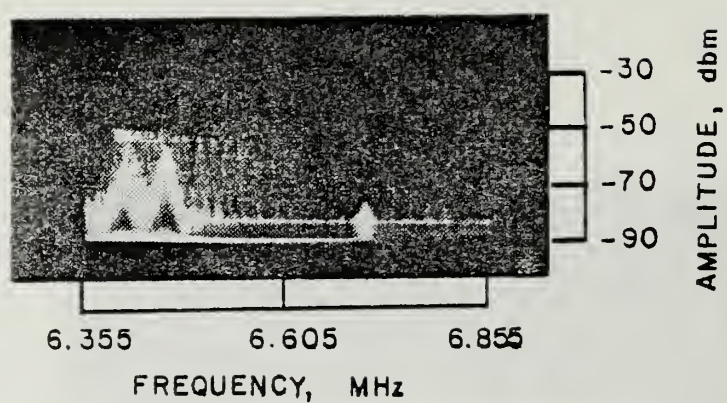
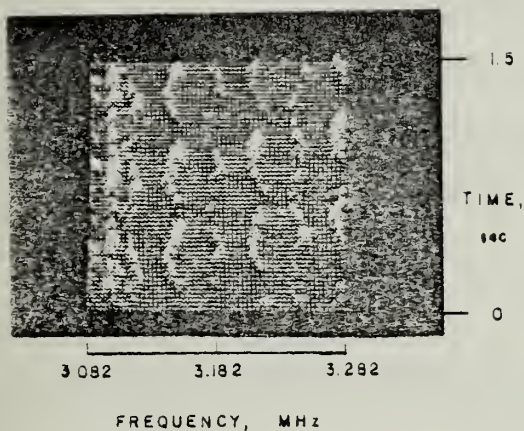
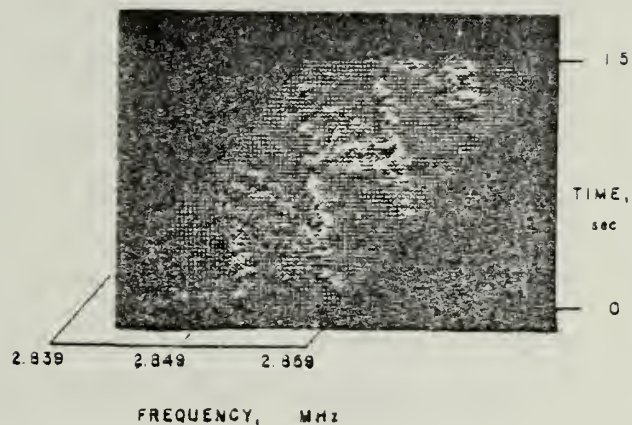


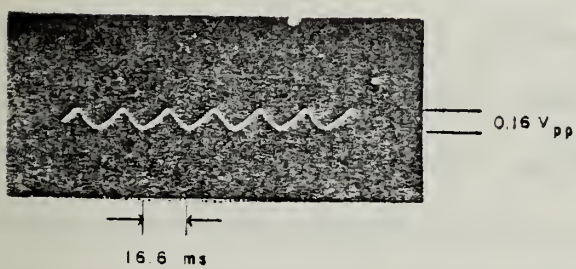
Figure 5. Signals in presence of parasitic oscillations from CU-1099 multicoupler.



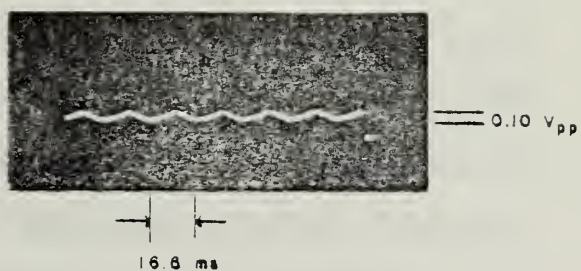
(a)



(b)



(c)



(d)

Figure 6. Bench tests on CU-1099 multicoupler.

3. INTERMODULATION PRODUCTS

Serious intermodulation (IM) product levels have been identified at the outputs of multicouplers employed at many HF receiving sites. Examples of such undesired signals are provided, along with comments on receiver performance degradation from these undesired signals. In addition some common misconceptions about IM susceptibility specifications are discussed.

3.1 MULTICOUPLER-GENERATED INTERMODULATION PRODUCTS

An example of an IM product observed at the output of a CU-1099 antenna coupler, at a site on the east coast of the U.S.. is shown in Figure 7. The very wide band signal found near 29.2 MHz contained distinct modulation components over a 200 kHz wide band which are visible in the 3-axis view. The IM signal strength was on the order of -60 to -70 dBm. The data in Figure 7 were taken during the late evening hours, at a time when HF signals above 20 MHz normally did not propagate. Yet an R390 receiver tuned to the signal identified the modulation as program material broadcast by the British Broadcasting Corporation (BBC) from a London transmitter, on a frequency of approximately 6 MHz. Assuming that an HF BBC broadcast signal is typically 60 to 8 kHz in width, the 29.2 MHz IM signal was spread to at

least 25 times the original bandwidth. This would imply that the data in Figure 7 represented about a twenty-fifth order IM product. The 29.2 MHz IM signal was one of several distinct and separate IM products with the same program material identified throughout the HF band. Probably these signals were caused by nonlinear intermixing of the very strong 6 MHz BBC transmission with several other strong signals rather than as a product of only two such signals.

These intermodulation products began to appear in the multicoupler output during the early evening hours. With darkness over the Atlantic Ocean, ionospheric absorption of HF signals from Europe decreased and received signal strengths increased. Very strong HF signals were observed from the BBC, Radio-Free Europe, Radio Netherlands, Radio Prague, Radio Moscow, and other HF broadcast transmitters. Most organizations were simulcasting program material on multiple frequencies. Many were employing antennas beamed toward the North American audience. Obviously transmitter power levels were high. This conglomerate collection of very strong HF signals simply exceeded the dynamic range of the CU-1099 multicoupler operation. The IM products in Figure 7 show only one example of hundreds of IM products found at the multicoupler output during the evening hours.

To further investigate the IM product generation phenomena, a relatively quiet portion of the HF spectrum was found between 3.470 and 3.490 MHz. Multicoupler outputs for six low-band sector beams of the CDAA antenna were examined (see Figure 8). Sectors 1 and 3 showed a few low level signals and short duration bursts of atmospheric noise. Sectors 4 and 5 showed some signal activity. Sector 6 was very quiet. Sector 2, which pointed toward Europe, showed continuous IM signal activity across the band being observed. Sector 2 was saturated with IM products across most of the HF band.

Intermodulation products found in the multicoupler output at a European HF site are shown in Figure 9. The spectrum analyzer displayed the 0 to 10 MHz band and the view shows both HF signals and intermodulation products. The three strongest signals were in the 1 to 2 MHz range, and they were identified as originating from two AM broadcast stations and a radio teletype transmitter. All three transmitters were within 12 miles of the receiving site. All three transmitters produced signal levels which exceeded -20 dBm at the multicoupler output. All other signals exceeding -60 dBm in Figure 9 were examined with an HF receiver, and they were all identified as IM products of the three strong signals in the 1 to 2 MHz region. IM products exceeding -65 dBm were identified up to 18 MHz.

Other signals of primary interest were all at lower signal levels and were often obliterated by the IM products.

Another view of HF signals and IM products at the European site is shown in Figure 10. The 3-axis view covers the 0 to 100 MHz band of frequencies and shows the signal and IM product population at the output of a typical multicoupler. The multicoupler had a low-pass filter with a nominal cut-off frequency of 35 MHz in its input stages. In normal operation no signals should appear above 35 MHz. However, the lower view of Figure 10 shows signals up to and probably well beyond 100 MHz. The entire signal and IM product population appeared to fade up and down in strength across the frequency range observed as IM product generation changed. All signals above about 35 MHz were IM products from strong signals inside the multicoupler frequency range. A large portion of the signal population below 35 MHz was also from IM products. The IM product population was far too large to consider individual analysis of products. The 3-axis view provided a summary type of presentation which was composed of many hundreds and perhaps even thousands of IM products.

3.2 SPECIFICATIONS FOR IM PRODUCT SUSCEPTIBILITY

Three standard methods of testing an amplifier for IM product susceptibility have been used. These are (1) a single signal test, (2) a two-signal test, and (3) a broadband white noise test. The single signal test is generally considered to be inadequate, and will not be discussed. The wideband white noise test is the most comprehensive type of test. It provides an accurate means of determining how a wideband amplifier will respond to an actual operating environment containing a multiplicity of signals where a large number of strong signals approach the dynamic range of the amplifier. However, a suitable white noise test requires highly specialized equipment and trained test personnel.

The most common method for IM product generation by an amplifier involves injecting two strong discrete frequency signals into the amplifier input and measuring discrete frequency outputs over the total bandwidth of the amplifier.

A major difficulty with the two-signal test is in the proper interpretation of test results. A two-signal test does not duplicate the effect of the multiple frequency HF environment on an amplifier. When an amplifier's IM susceptibility is specified in terms of two discrete frequency signals at a given input voltage level, the

implication is that as long as no signal exceeds that specified voltage no harmful IM products should be generated. However, multiple signals, wideband signals, or wideband noise at the specified input voltage or at a lower voltage will produce more serious IM products than implied by a simple two-signal test.

To accurately interpret the results of a two-signal IM test, the amplifier being tested must be viewed as an input power limited device. A certain level of input power (or a certain wideband rms voltage at the input) can be accepted by the amplifier without becoming nonlinear. When input power exceeds this level, IM products are produced.

The maximum input power level that an amplifier can accept without IM distortion can be determined from a two-signal test by calculating or measuring the total input power of the two input signals. This power level must not be exceeded by the total sum of the input power of all actual signals for units installed in field operations. Thus, a satisfactory two-signal IM test specification must account for the actual total power level of the signal environment supplied to the amplifier by an antenna.

Given a test specification that two signals of rms voltage V will not produce amplifier IM products exceeding X

dB below the output signal levels, the maximum input power level, $P_{IN(max)}$, can be calculated by:

$$P_{IN(max)} = 2(V^2 \operatorname{Re}\{Y\})$$

where $P_{IN(max)}$ is in watts, V is in volts, and Y , the amplifier input admittance, in mhos. A more common form of this equation gives the input power level in dBm:

$$P_{IN(max)} \text{ dBm} = 10 \log(V^2 \operatorname{Re}\{Y\}) + 33$$

In actual practice the total rms input voltage, $V_{IN(T)}$, can be measured during either a two-tone test or during actual operation by connecting an appropriate RF rms voltmeter across the amplifier input terminals. When the maximum acceptable value of $V_{IN(T)}$ is determined for a two-signal test, then any actual measure $V_{IN(T)}$ from an antenna which exceeds the two-tone test value will produce excessive IM products. For IM products to be within the

specified limits,

$$V_{IN(T)} < V_{IN(T) (max)}$$

where

$$V_{IN(T) (max)} = 2V.$$

Field measurements from a typical field antenna have indicated that total rms signal levels from a 70 ohm feedline into a multicoupler were often as high as 500 mV rms. In this case a suitable two-tone test voltage, V, must be at least 250 mVrms, and the total rms input voltage, $V_{IN(T) (max)}$, must be at least 500 mV rms.

The performance specifications from the manual for the CU-1099/FRR Antenna Coupler are considered next. The manual states that IM products from a pair of 250 mV input signals will not exceed -60.5 dBm. With a nominal gain of 1.5 dB, the two output signals will have a power level of 1.0 dBm, and the nominal dynamic range for the CU-1099/FRR multicoupler at the specified input level is 61.5 dB. Now consider a practical application where field personnel wish to function with signal levels at -100 dBm. If two other signals at the level specified for the IM tests are also being received, then IM products exist at 60.5 dBm or 39.5 dB higher than the low level signal which must also be

received. If the two strong signals produce IM products at the frequency of the weak desired signal, then the weak signal clearly cannot be received because of IM interference.

Ensuring that all IM products will be below the level of weak received signals may not be practical in all cases. Given the fact that some received signals have a power level of -10 dBm, a requirement to keep all IM products below -110 dBm presents a requirement for an amplifier with a 100 dB dynamic range. An amplifier with a 100 dB dynamic range would have eliminated all cases of IM products described in earlier sections of this report. While such an amplifier can probably be constructed, the cost would almost certainly be higher than the cost of a CU-1099/FRR or equivalent multicoupler. Some compromise between the 60 dB dynamic range of the CU-1099/FRR and the desired 100 dB dynamic range probably represents a more practical, cost effective solution.

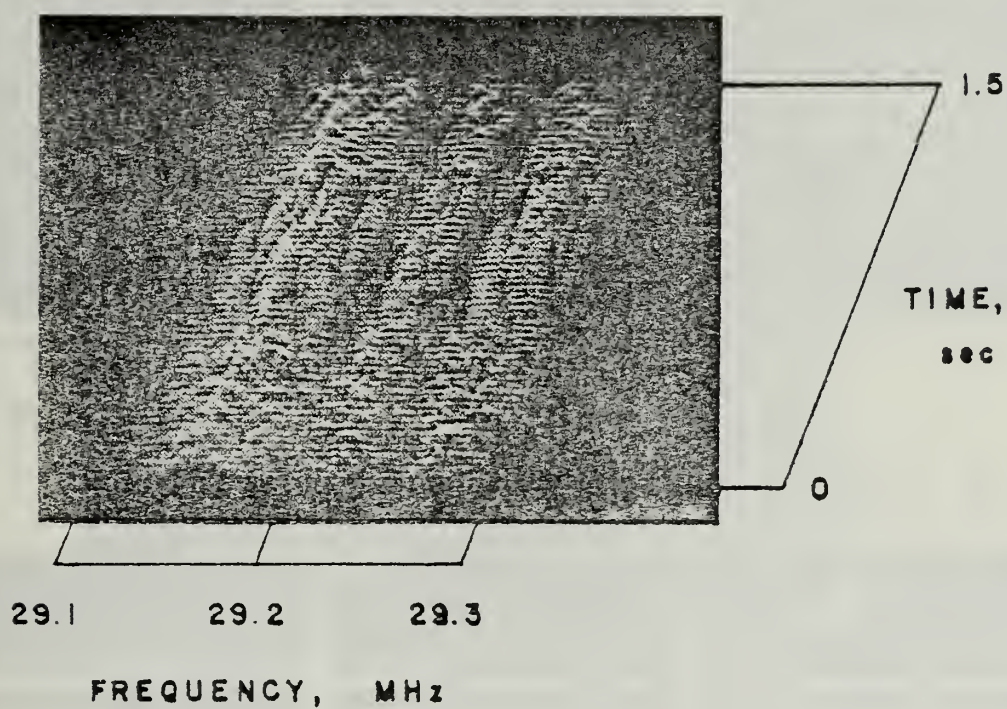


Figure 7. Intermodulation product at 29 MHz from signal at 6 MHz

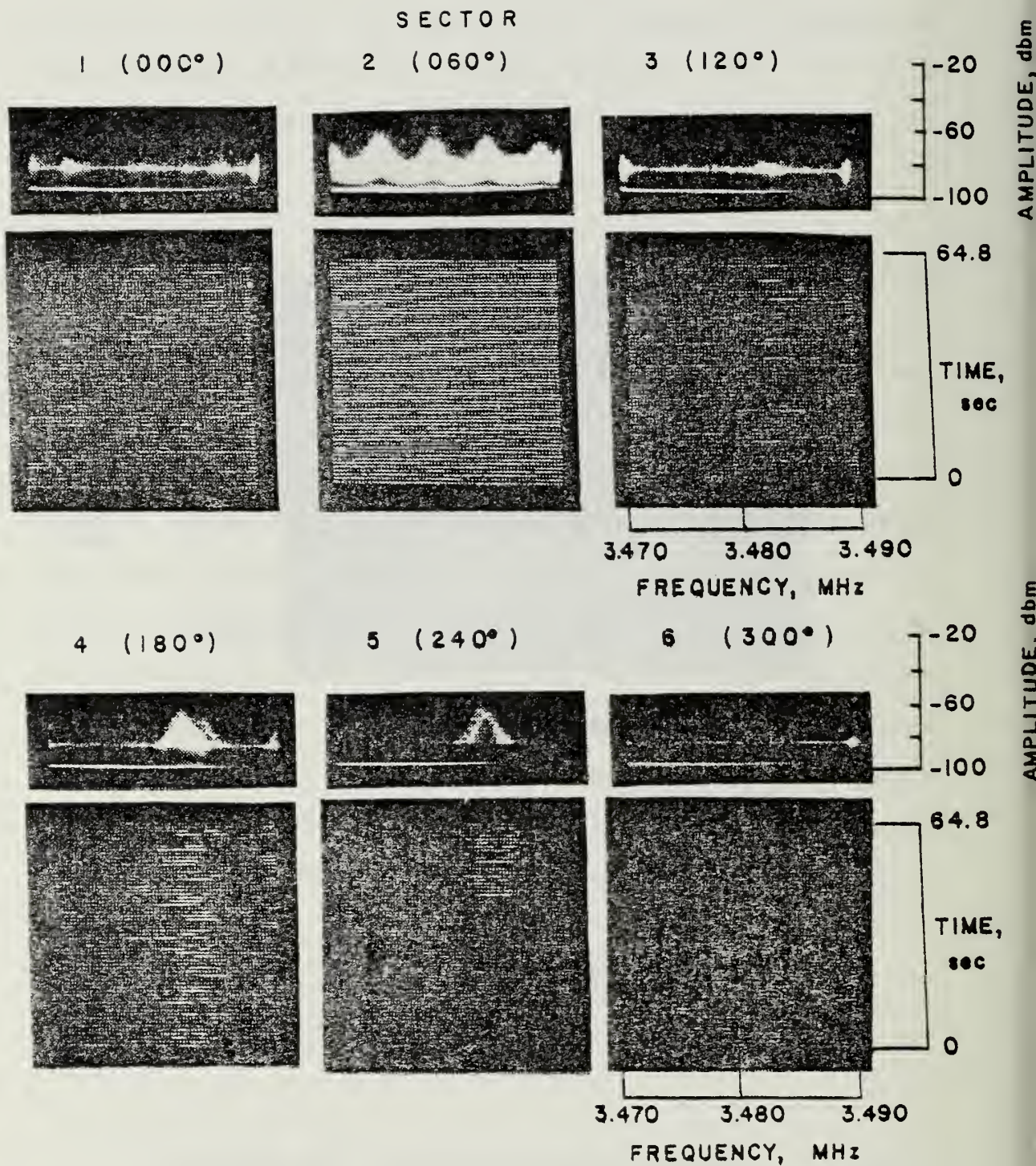


Figure 8. Comparisons of multicoupler outputs from 60 degree sector beam antennas.

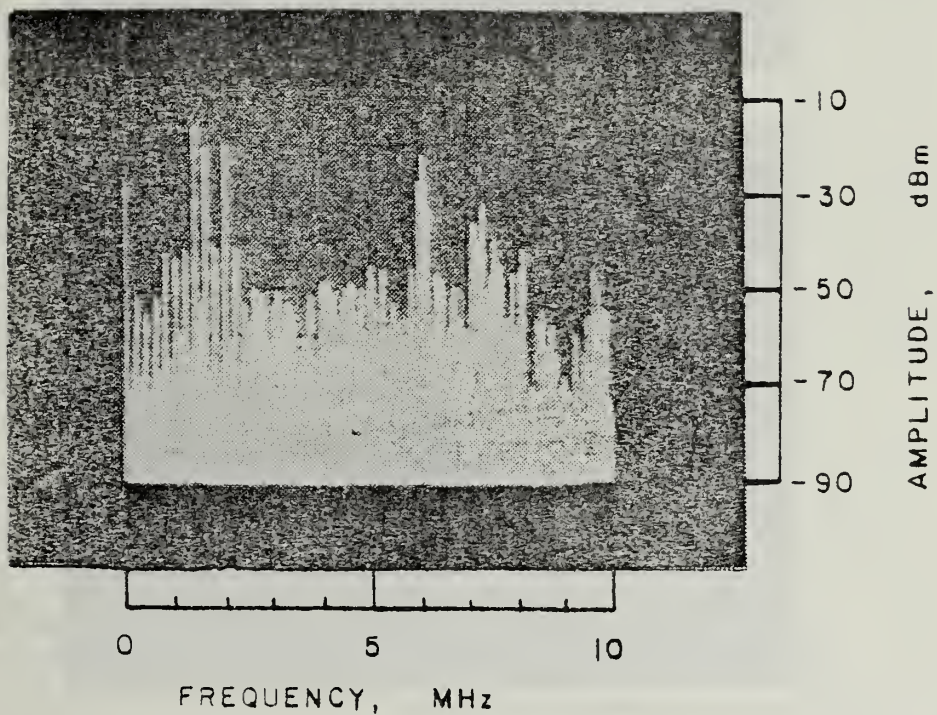


Figure 9. Intermodulation products across a 10 MHz spectrum from three discrete signals.

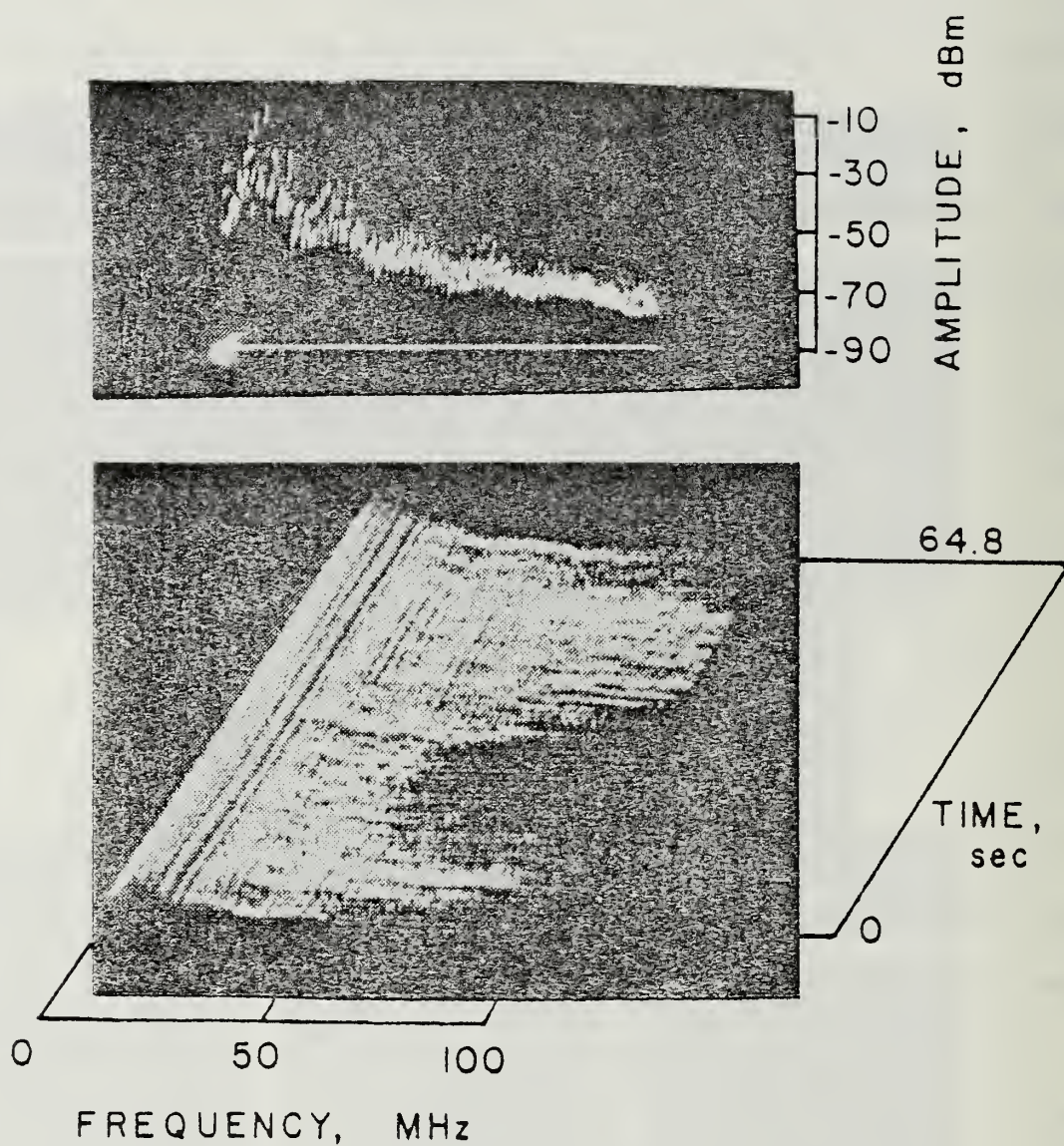


Figure 10. Intermodulation products across a 100 MHz spectrum as overdriving signals fade in and out.

4. LABORATORY TESTS OF INTERMODULATION PRODUCTS

A multicoupler's specifications indicate that signals of a certain voltage can be applied to the amplifier and IM products will not exceed prescribed levels at the output. Yet during field measurements, under normal conditions, serious IM products were found, which exceeded their prescribed levels even though no input signal exceeded the maximum level specified. To better define the problem, laboratory tests were performed on the generation of IM products in typical multicouplers and amplifiers under controlled conditions.

Four models of amplifiers were examined. They were:

- a. CU-1099/FRR Antenna Coupler;
- b. CU-1382F/FRR Antenna Coupler;
- c. CU-1382G/FRR Antenna Coupler;
- d. Hewlett-Packard Model HP 461A Amplifier.

A fifth unit, the CU-872/FRR Antenna Coupler, a vacuum tube multicoupler, was examined, but not in the same depth as the others.

The test equipment configuration is shown in Figure 11. During initial tests a resistive noise generator was used as a wideband signal source. The noise was amplified by 60 to 80 dB, as required. However, the broadband amplification of noise was found to be a major instrumentation problem. During later tests a pseudo-noise source was used which consisted of a laboratory signal generator which was frequency modulated by noise. Signals from discrete frequency and wideband noise sources were added in a resistive summing network. The summing network output voltage was then used as the input signal for the amplifier under test.

Another instrumentation difficulty encountered during the tests was the summing of input signals without generating intermodulation products in the summing process. Careful construction practices and instrumentation operation minimized this problem, but did not entirely eliminate unwanted IM products in the input signal. Figures 12 through 18, which document IM tests, all show some degree of input signal IM product effects. While these undesired signals complicate the examination of results somewhat, they do not prevent the analysis of amplifier IM.

Pairs of photographs are presented in Figures 12 through 18 representing the amplifier input signal (left

photograph) and the amplifier output signal (right photograph). A frequency range of 0 to 50 MHz is covered in each view and signal levels are shown in dBm. Instrumentation operation, including spectrum analyzer performance, was monitored during all tests to ensure that test equipment-generated IM products were controlled and known.

Figure 12(a) shows the performance of a CU-1099/FRR multicoupler at its IM product specification condition. Two 250 mV signals were applied to the amplifier input. Harmonic and IM products were at least 50 dB down at the input. At the output at least three products exceeded the -50 dB level. This particular CU-1099/FRR did not meet specifications.

Figure 12(b) shows the performance of this same multicoupler with three 250 mV signals applied to the input. Input IM products were at least 43 dB down from the input signals. At the output five spurious components exceeded the -43 dB level. Figure 12(c) shows this amplifier with input signals decreased to the point where the total rms input voltage equaled that of Figure 12(a). In Figure 12(c) the number of IM products was greater than the number in Figure 12(a), but their severity more closely resembled Figure 12(a) than Figure 12(b). The amplifier was less

saturated in Figure 12(c) than in Figure 12(b).

Figures 13(a) through (c) parallel Figures 12(a) through (c). but the test signals into the CU-1099 were reduced to 200 mV. Even so, this amplifier still produced IM products which exceeded allowable levels.

Figures 14 and 15 document tests run on the CU-1382F and CU-1382G multicouplers. Figures 14(a) and 15(a) show each amplifier's performance at the specified input voltage (two 500 mV signals). Figures 14(b) and 15(b) show the amplifier's performance with the number of input signals increased to three. Even with the three-signal condition, no discernible IM products were found. Although the measurement system arrangement did not permit the examination of levels more than 60 dB below the signal levels, it appeared that both the CU-1382F and CU-1382G amplifiers met and exceeded their IM specifications.

Tests of the CU-872 multicoupler were limited to subjective comparisons with the CU-1099. The observations suggested that conditions that caused the CU-1099 to degrade also caused the CU-872 to generate IM products. However, the degradation of performance of the CU-872 was much more gradual than that of the CU-1099.

A general-purpose wideband amplifier, the HP-461A, was tested under a range of input signal conditions. Figures 16(a) through (d) show the HP-461's performance with two, three, four, and finally five 2 mV input signals. As the number of signals increased, the total rms input voltage and the total input power increased. At the output the amount of intermodulation also increased.

In Figures 17(a) through (d) the number of signals again increased from two to five. The total rms input voltage remained constant at 4 mV. The amount of intermodulation did not increase as the number of signals increased because the total input power did not increase.

In Figure 18 the HP-461A amplifier was tested with four signals and wideband noise. In Figure 18(a) the four discrete frequency signals can be seen in the input and output views. The input level of these signals was high enough to cause discernible IM products in the output. Figure 18(b) shows band-limited but relatively wideband noise into and out of the amplifier. Figure 18(c) shows this noise plus the four signals of Figure 18(a). The output photograph of Figure 18(c) shows the effect of wideband noise on IM product generation. The effect of this combined multiple signal and noise environment at the saturation level of a typical amplifier is rather demonic.

Figure 18 is a laboratory test. The sector 2 photograph of Figure 8 is a real-world field measurement bearing striking similarities to Figure 18.

During the laboratory testing program out-of-band attenuation specifications for multicouplers were reviewed. A specification for attenuation at frequencies above the HF band is shown in Figure 19(a) for the CU-1382 multicouplers. A 40 dB minimum attenuation value is given, except at the 68 to 95 MHz frequencies where less attenuation is allowed. This was also the frequency range of maximum amplitude of parasitic oscillations of the CU-1280 multicoupler (see Figures 1 and 2). This curious relationship obviously needs careful examination, and some aspect of the multicoupler specifications and design needs to be altered to avoid the harmful out-of-band parasitics.

Attenuation at frequencies above the HF band is shown in Figure 19(a) for the standard CU-1382F multicoupler. The allowable attenuation for the phase coherent version CU-1382G multicoupler is shown in Figure 19(b). The minimum attenuation above 40 MHz is 30 dB at all test frequencies, and the relaxation in attenuation near 78 MHz did not apply to the phase coherent version.

For both versions of the CU-1382 multicoupler

attenuation requirements below the HF band are shown in Figure 19(c). The standard CU-1382 model provides 50 dB of attenuation at frequencies below 1.6 MHz while the phase coherent version provides 30 dB. The less stringent attenuation specifications both above and below band for the phase coherent version of the CU-1382 multicoupler is certainly undesirable. The phase coherent version is employed in critical beamforming applications where maximum performance is desired. But it is much more susceptible to unwanted intermodulation and mixing products from out-of-band signals.

The CU-1382F and CU-1382G (phase coherent) multicouplers performed much better in laboratory tests than the other multicouplers and amplifiers examined. However, at a European site equipped with the CU-1382 series multicouplers, IM products were found during late afternoon and nighttime hours. Apparently, the actual signal environment at a CDAA site produced more total signal input power than specified for CU-1382 tests. This suggests that improved data needs to be collected on the maximum multicoupler input power at such sites, and that this power level needs to be integrated into multicoupler specifications. The generation of excessive IM products in the CU-1382 multicouplers in actual field operation but not in the laboratory tests emphasized the need for realistic

relationships between field operation and laboratory tests. The laboratory tests were conducted at specified levels. These levels adequately represented daytime signal levels at the European site, but not nighttime conditions. A two-tone level of about 1000 mV and a dynamic range at least 80 dB might have been a more appropriate specification value.

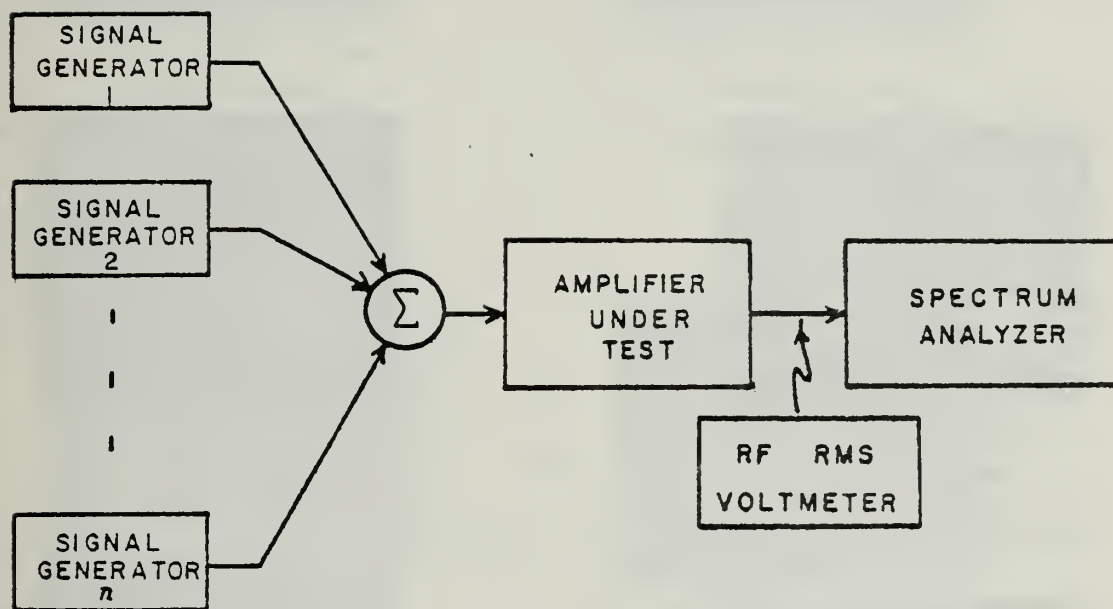
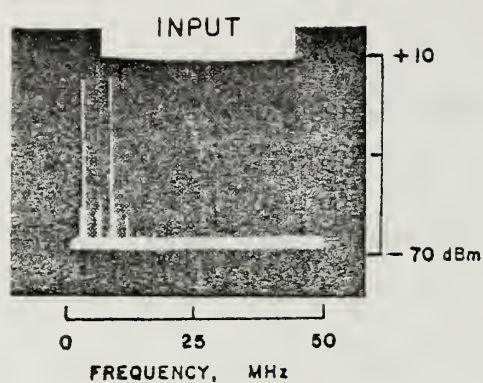
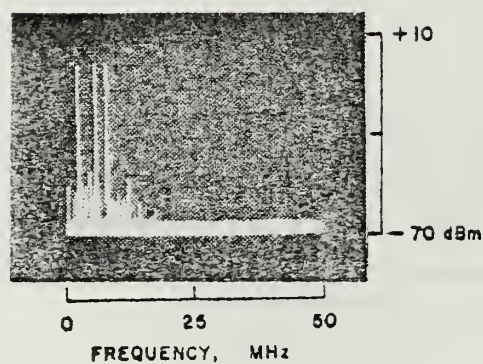
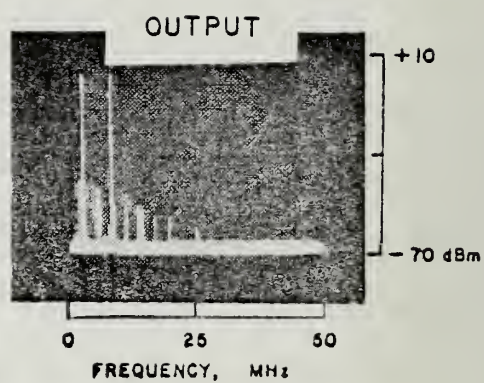


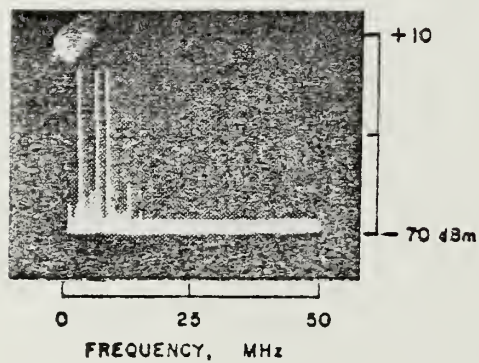
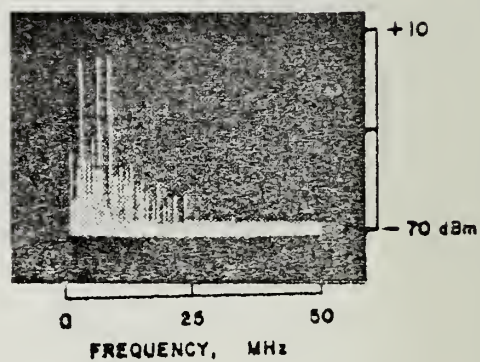
Figure 11. Laboratory test configuration for study of intermodulation products.



(a.)



(b.)



(c.)

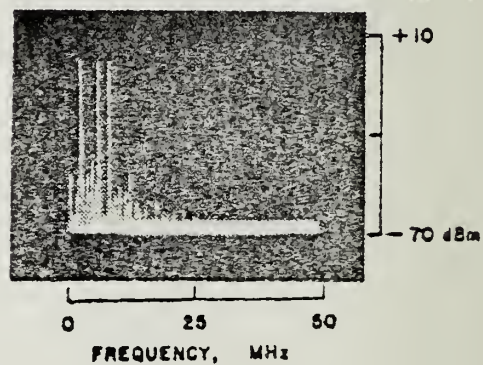
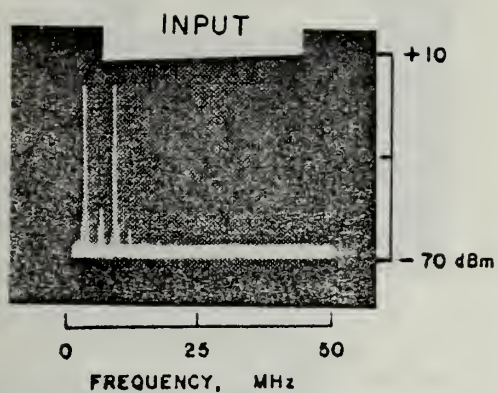
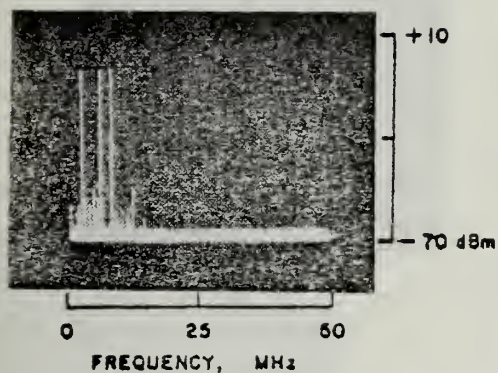
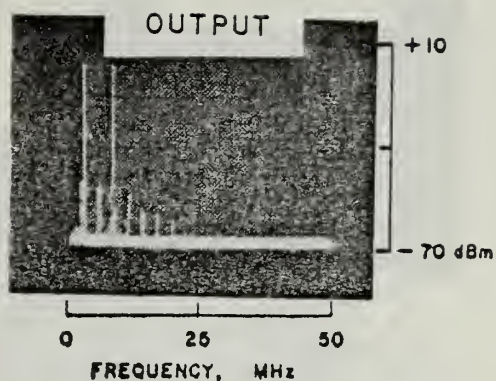


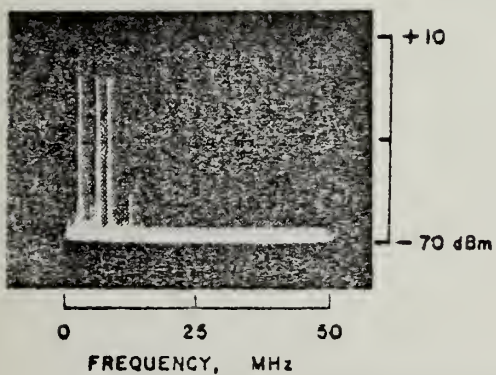
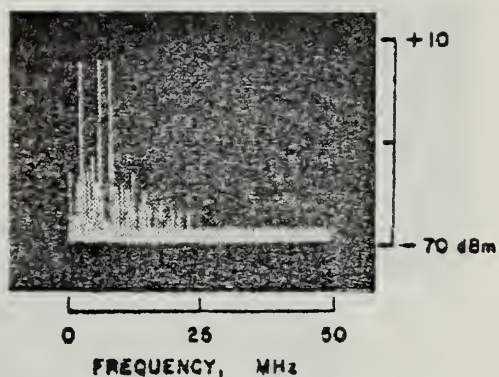
Figure 12. IM performance of CU-1099 multicoupler.



(a.)



(b.)



(c.)

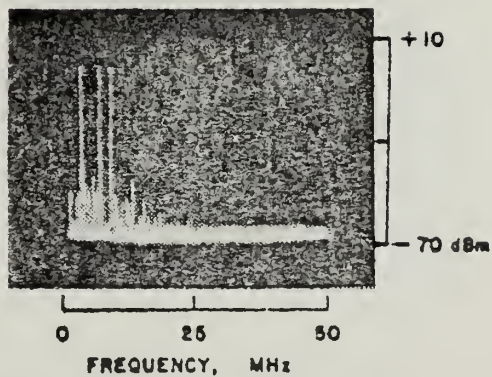
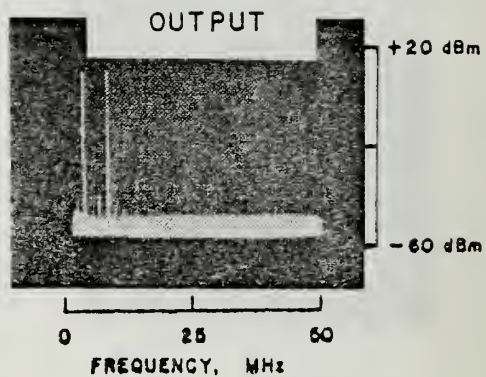
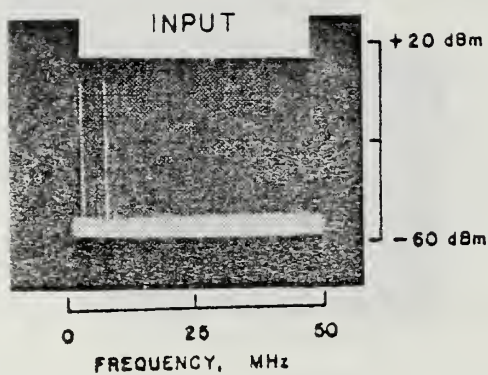
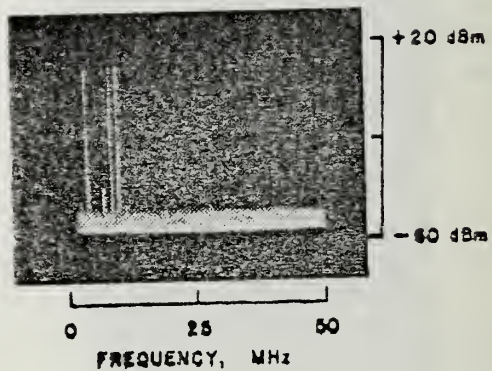
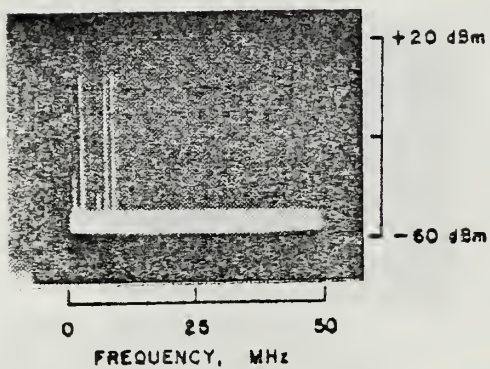


Figure 13. IM performance of CU-1099 multicoupler, derated to 80% of specification level.

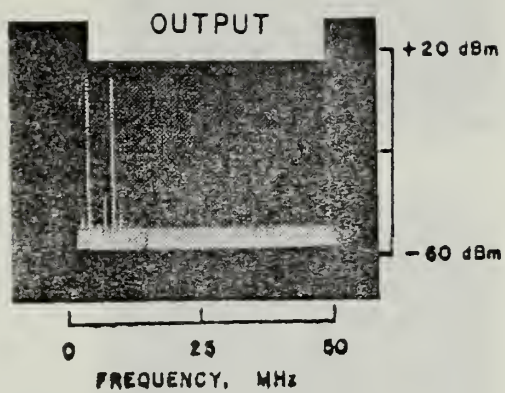
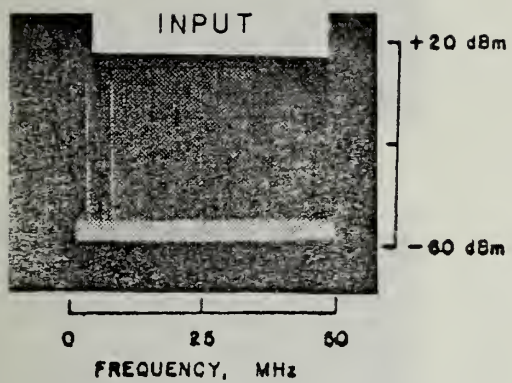


(a.)

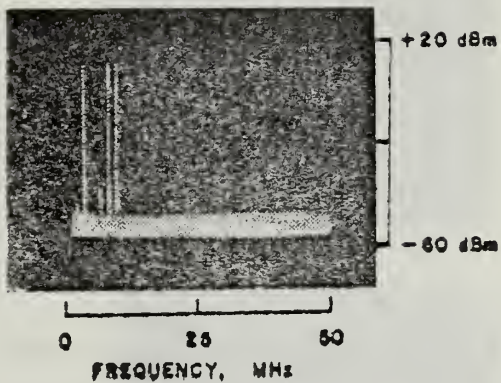
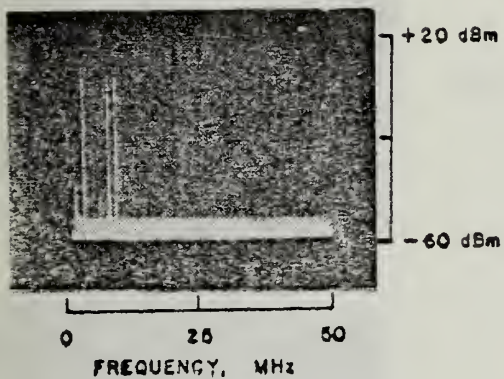


(b.)

Figure 14. IM performance of CU-1382F multicoupler.



(a.)



(b.)

Figure 15. IM performance of CU-1382G multicoupler.

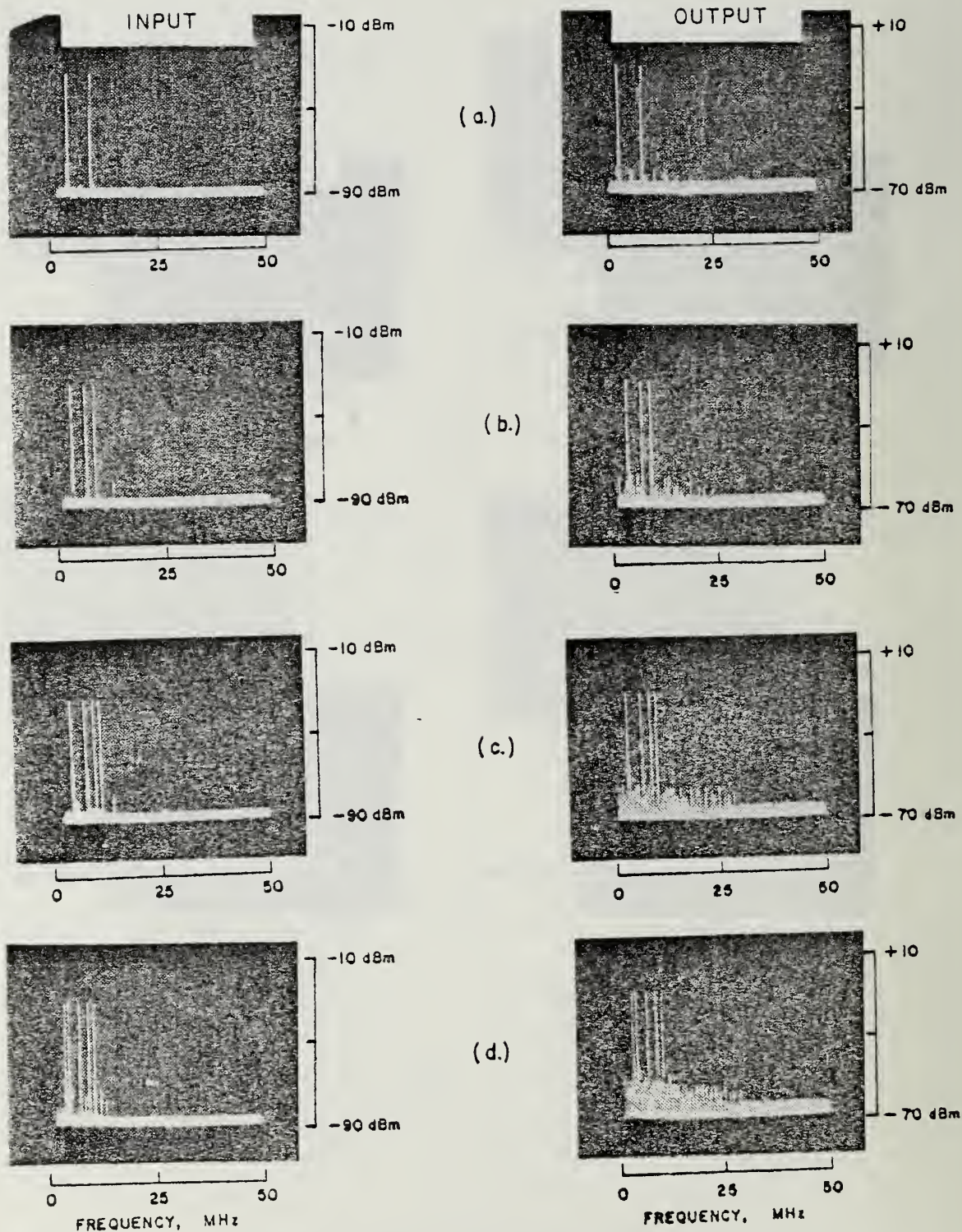
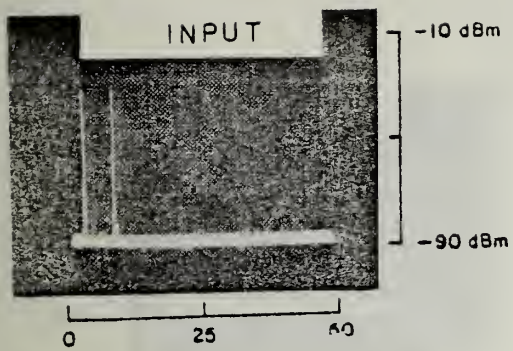
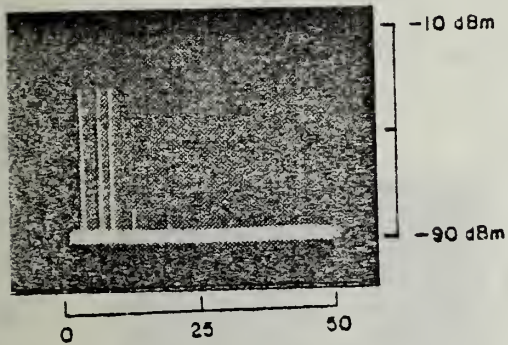
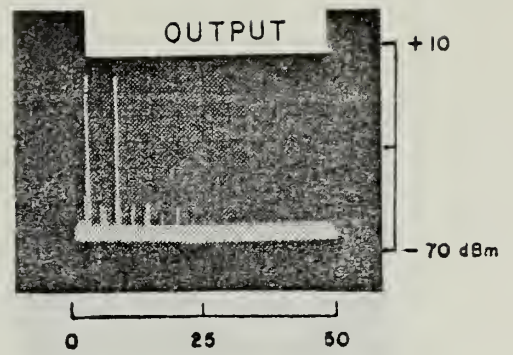


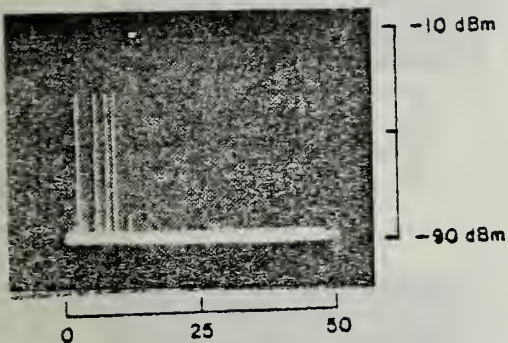
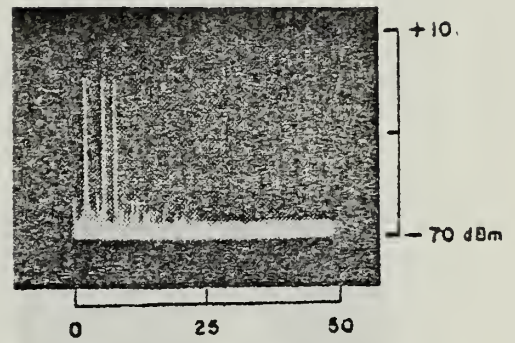
Figure 16. IM performance of HP-461A general purpose amplifier, with all input signals at specific level.



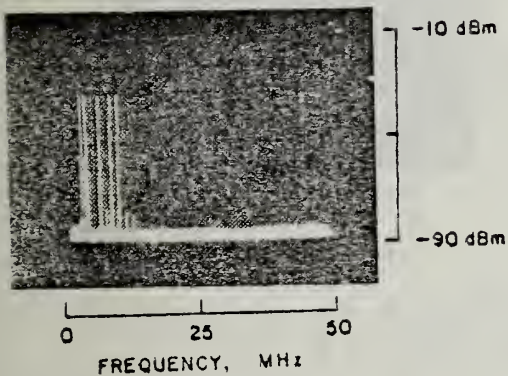
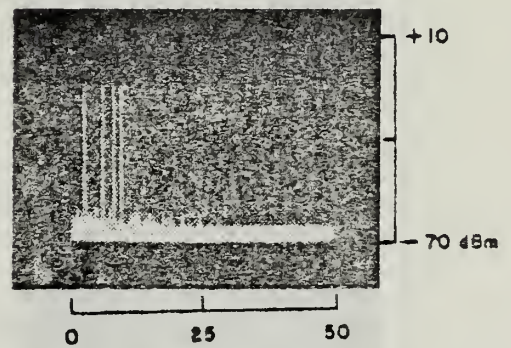
(a.)



(b.)



(c.)



(d.)

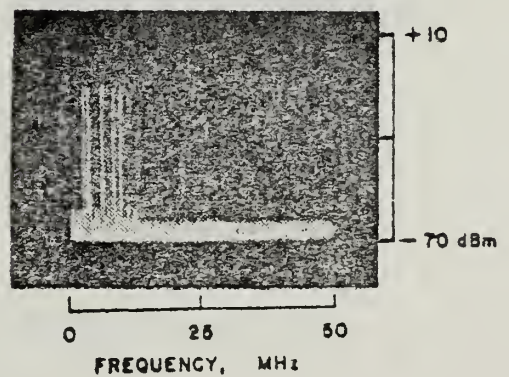
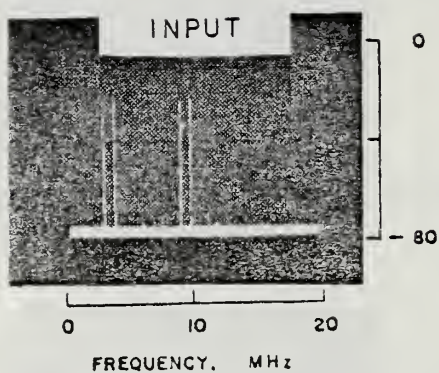
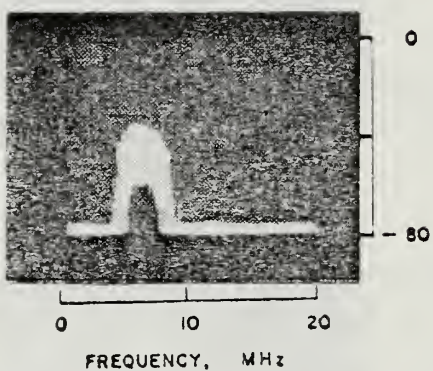
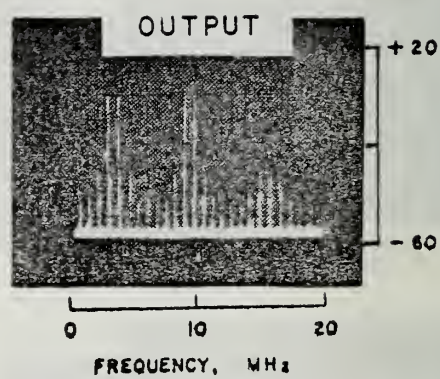


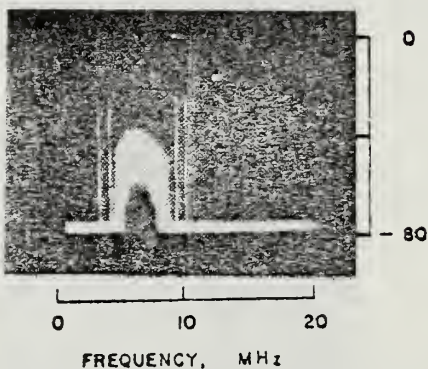
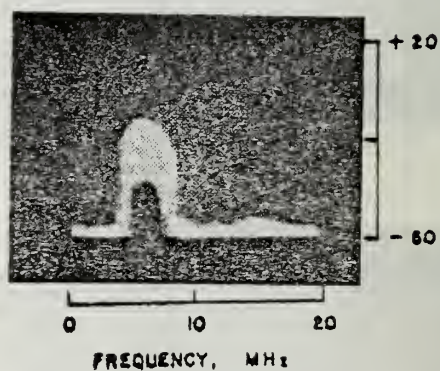
Figure 17. IM performance of HP-461A general purpose amplifier with rms total input signal held at constant level.



(a.)



(b.)



(c.)

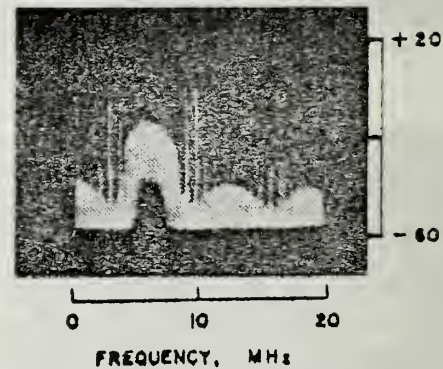


Figure 18. IM performance of HP-461A general purpose amplifier with both signals and wide band noise.

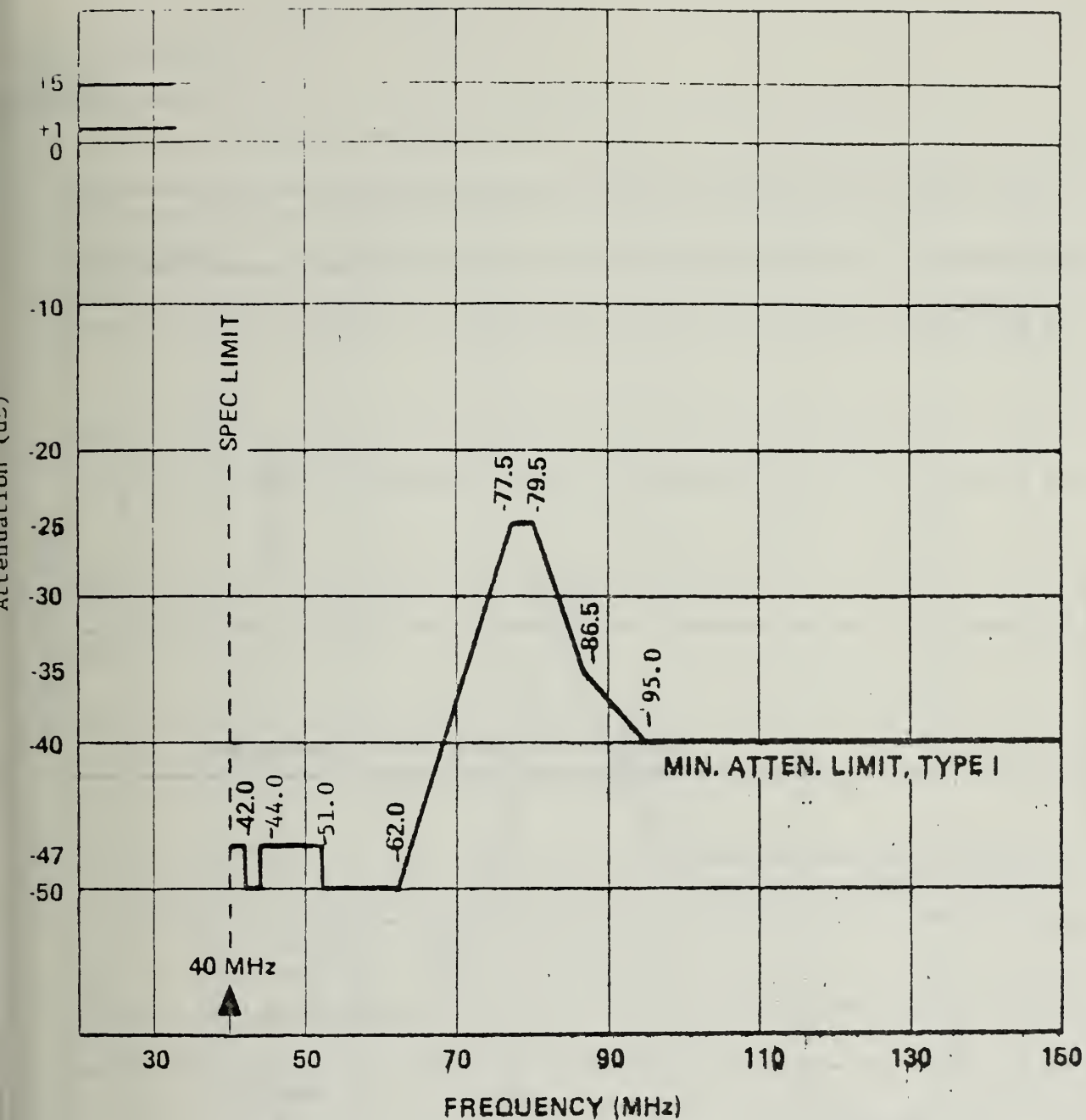


Figure 19a. RF FILTER HIGH FREQUENCY SPECIFICATION FOR CU-1382F MULTICOUPLER.

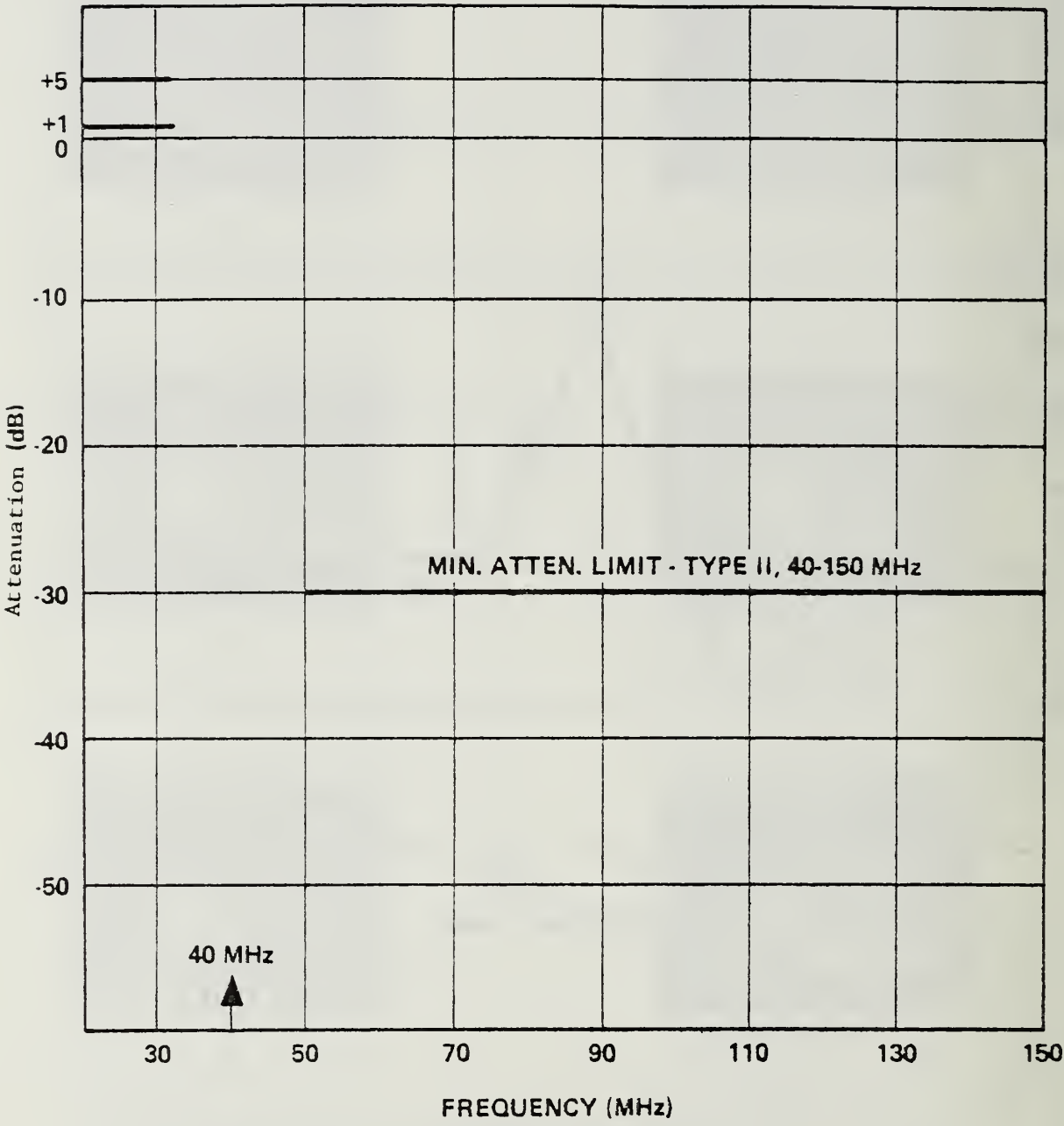


Figure 19b. RF filter high frequency specification for CU-1382G multicoupler.

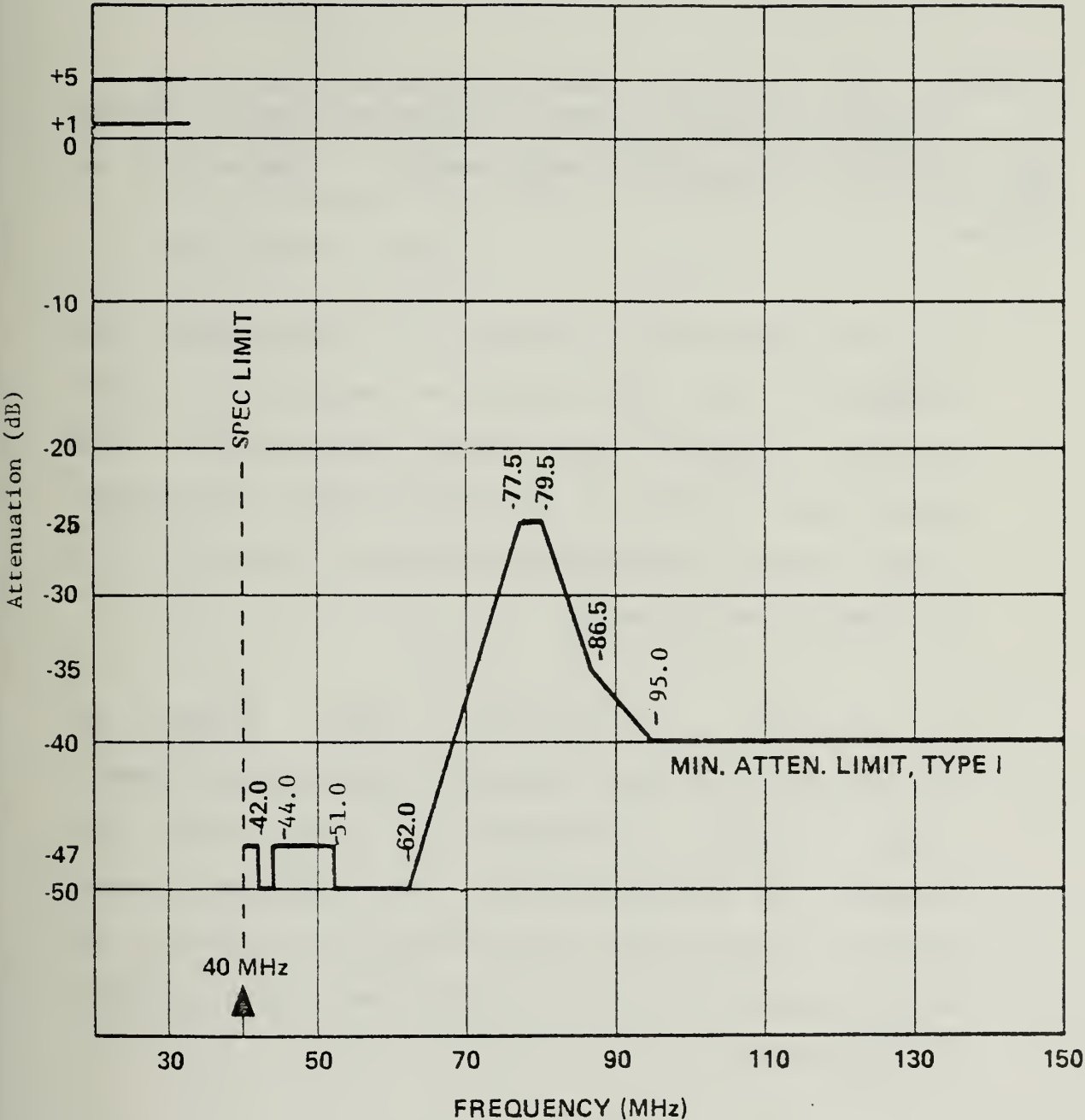


Figure 19c. RF filter low frequency specification for CU-1382F and CU-1382G multicouplers.

5. CONCLUSIONS

A number of specific conclusions were reached during the field and laboratory measurements. These are as follows:

a. The current specifications for multicouplers are inadequate, and they should be revised to better represent practical field signal environments. The peak signal input for two-tone IM tests, the dynamic range, and the out-of-band attenuation specifications all need to be increased.

b. Parasitic oscillations, both in-band and out-of-band, seriously reduce the operational dynamic range of many multicouplers in field sites and increase IM susceptibility. In addition, in-band parasitic oscillations cause serious and strong RFI which prevents the reception of signals over widebands of frequencies.

c. IM products observed at sites were so severe at nighttime as to almost negate site operational capability. In addition, at one European site, below-band strong signals caused IM product levels which rendered the omni antenna derived from CDAA

elements virtually unusable, both day and night.

d. All sites visited needed improved test equipment to identify parasitic oscillations and IM products and aid maintenance personnel in minimizing these unwanted and harmful signals.

6. RECOMMENDATIONS

The following actions are recommended in order to improve the multicoupler situation:

a. A comprehensive study be made to determine the full-extent of the parasitic oscillation and intermodulation problems at all CDAA sites;

b. A comprehensive set of measurements be made to determine the dynamic range of signals to be encountered under normal conditions, at all points in the RF chain, at all CDAA sites;

c. A policy be established to determine the dynamic range of signals to be received at proposed receiving sites before site construction;

d. Further procurements of multicouplers specify a dynamic range in the passband of 80 to 90 dB, and attenuation out-of-band of 50 dB at all frequencies above 40 mc and below 1.6 mc;

e. Further procurements of multicouplers specify intermodulation component susceptibility figures in terms of total rms input voltage or total input power;

f. Maintenance procedures and field tests be promulgated to permit timely discovery of parasitic oscillations and intermodulation products;

g. All CU-1099/FRR multicouplers be replaced or modified to improve performance.

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